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(54) Automatic aircraft landing system calibration.

(57) To allow calibration of an airfield microwave landing system an aircraft carries a microwave landing system receiver and a TV camera together with a data processing system. The aircraft is guided in to land by the microwave landing system and the positions of the airfield landing lights are observed by the TV camera, the images from the TV camera are processed by the data processing system and the position and orientation of the aircraft relative to the runway at each point in its landing approach is calculated trigonometrically by the data processing system.

The aircrafts actual flight path and orientation can then be checked against the intended flight path and orientation and the necessary changes to the microwave landing system to eliminate any differences and so properly calibrate the microwave landing system can be calculated.

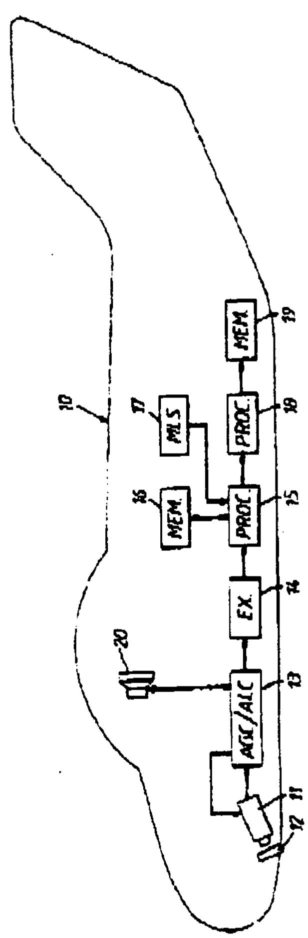

Fig.2

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line of lights at the aircraft or by the angles subtended by any pair of lights 4a, 4b, 4c, of course the angle subtended by the whole line of lights will allow the distance to be measured more accurately because it provides a longer base line.

The sideways position of the aircraft relative to the runway axis 3 can be determined by measuring the angles of the three lines of runway lights 1a, 1b, 1c relative to the base formed by the lines of threshold lights 4a, 4b, 4c.

The height of the aircraft can be determined by the angle of the apex of the triangle formed by the two side lines of runway lights 1b, 1c taken in combination with the distance which has already been calculated. Of course any specific arrangement of lights may also contain other useful geometric arrangements which can be used to cross-check these measurements.

A suitable sensor system to allow these measurements to be carried out is shown in Figure 2. An aircraft 10 carries a TV camera 11 which looks forward at the runway area through a filter 12. The filter 12 is arranged to exclude as much of the sunlit background light as possible in order to maximise the contrast of the runway lights relative to their background. The exact characteristics of the filter 12 will depend on precisely what lights are used, but for tungsten filament lamps with a colour temperature of about 2000 kelvin the spectral emission of the lamps will peak at about one micron wavelength whereas sunlight peaks at around 0.55 micron wavelength so by using a filter 12 rejecting radiation with a wavelength shorter than 900 nanometres a considerable increase in apparent contrast can be obtained. The use of the filter 12 also maximises the performance of the system in poor visibility since the longer wavelengths of radiation are scattered less by fog and mist, as a result the use of the filter 12 will allow the system to be used in poor visibility where it would otherwise not be possible to calibrate the MLS.

The characteristics of the camera 11 will also depend on the type of lamp used by the runway lights but for tungsten filaments lamps a silicon CCD camera sensitive up to a wavelength of about 1.05 microns would be especially effective.

The TV camera 11 has a telecentric optical system, that is to say the stop which the defines the rays entering the camera is located such that the centre of the ray bundle from any point in the cameras field of view reaches the image plane of the camera 11 normal to the image plane, the CCD sensor of the camera 11 is placed in the image plane so this will ensure that errors in focus do not effect the positional accuracy.

The angles subtended by the runway lights will obviously change dramatically as the aircraft approaches from a distance of several kilometers to landing where it will be some tens of meters from them so, in order to provide optimum measurement accuracy at all ranges, as the aircraft 10 travels along the approach path towards the runway 2 the camera 11 is provided with several alternative sets of optics (not shown) which are moved in front of the camera 11 as needed as the aircraft 10 moves. Provided the optical characteristics of each of the sets of optics are known and it is known at all times which set of optics is in use this will not effect the accuracy of the system. It would of course be possible to use a plurality of TV cameras 11 each with a single optical system and switch from one camera to another rather than a single camera and moving the optical systems. In the system shown two alternative optical systems are provided for the camera 11 one giving a field of view of 10o and the other giving a field of view of 45°.

A CCD sensor array in the camera 11 is a 2000 pixel by 1000 pixel array giving a total of 2000000 pixels points, and operates at a frame rate of 6.5 frames per second giving an output pixel rate of 15 mega hertz. When this camera looks at the angles subtended by a typical line of runway lights of length approximately 50 metres from a range of 25 metres so that the lights are at an angle of 45°, a 2000 pixel wide array will allow apparent length of about one part in 2000 to be sensed which corresponds to a movement of about 2.5 cm, thus a system of this type will provide enough accuracy of measurement to properly calibrate the MLS.

The digital output data from the TV camera 11 consists of a series of pixels or data points each of which has its brightness represented by a digital value together with synchronisation signals to allow the position of each of the pixels in the frame to be unambiguously deduced. A digital data output of the TV camera 11 passes through an automatic gain and level control (AGC/ALC) which examines the data stream and adjusts the sensitivity of the TV camera 11 in order to keep the signal level from the brightest points in the field of view, which will be the pixel points corresponding to the runway lights, near the top of the CCD sensors dynamic range so as to achieve maximum contrast. This sensitivity adjustment is carried out by varying the integration time of the CCD sensor. This integration time should be held to the minimum possible consistent with good contrast being achieved between the runway lights and the background because the aircraft 10 is moving and as a result the accuracy with which the position of the aircraft 10 can be measured relative to the runway will be limited by the fact that the aircraft moves during the integration period. A typical integration period is around 1 millisecond in which time an aircraft flying at a speed of 50 metres per second will cover 5 cm, so this source of error should not reduce the accuracy of the system below that required to calibrate an MLS. The data stream is then passed to a point feature extractor 14 which xtracts the point features from the

tem, instead of identifying key elements in the scene geometry and calculating the position of the aircraft from them it would be possible to use the mathematical technique known as damped least squares optimisation to successively adjust the estimated aircraft position and attitude until the error function made up of a weighted combination of the sums of the squares of the errors between actual and predicted positions of the lights is minimised. The advantage of this technique is that it would be resistant to corruption by a few of the light positions being omitted due to their not being detected by the light extraction system and all available data, that is the positions of all the visible lights, is used to obtain an optimum estimate of position, the disadvantage of this system is that it requires considerably more processing power than the other system in order to provide a real time output.

Although the system described carries out real time processing of the camera data on board the aircraft it would be possible to record the data, possibly after some preprocessing to reduce the amount of data that needs to be recorded, for later analyses.

Claims

1. Automatic aircraft landing system calibration apparatus comprising an aircraft carrying a TV camera, an image processing system and a data processing system, the TV camera being arranged to observe the runway landing lights and the image processing system being arranged to use the output from the TV camera to calculate the position of the aircraft relative to the lights and the data processing system being arranged to compare this calculated position with the aircrafts position according to the automatic landing system.

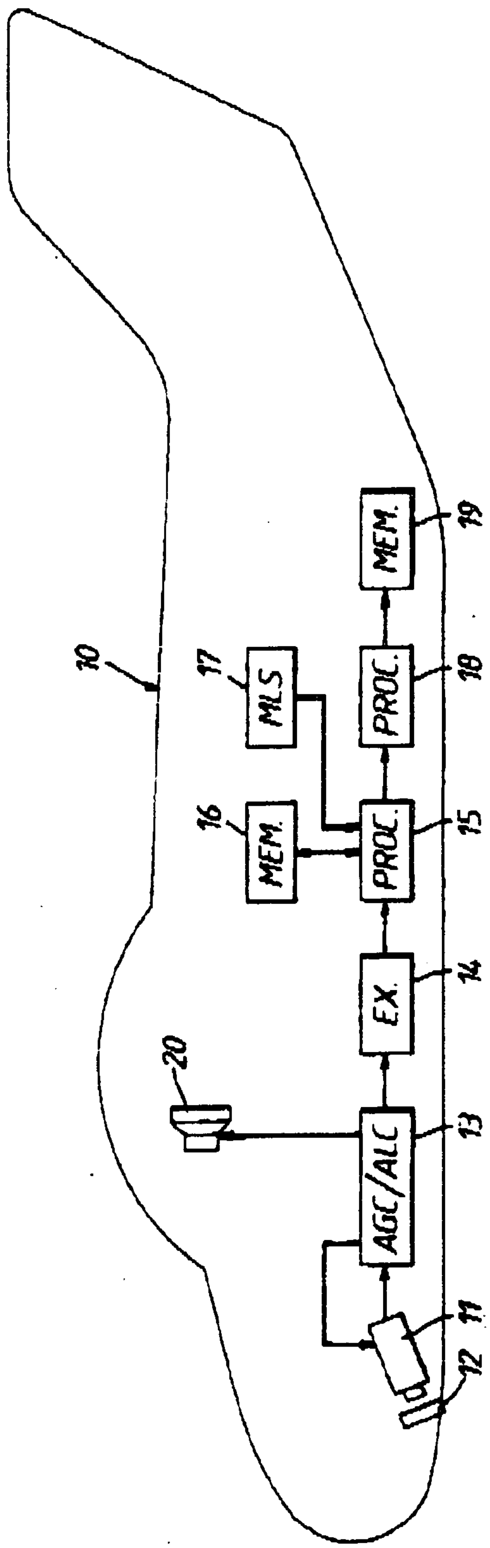

Fig.2